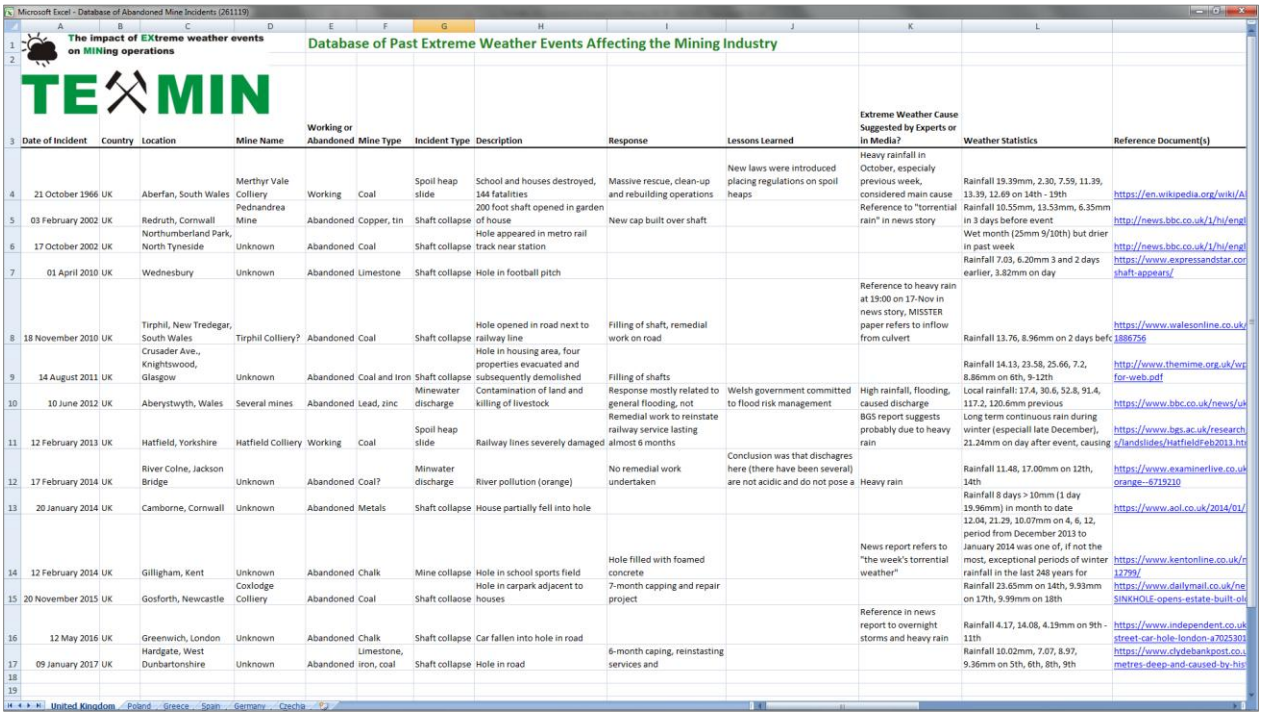
Identification and analysis of climatic conditions affecting the mining industry - short summary and chosen examples

Extreme weather and climate-related events can significantly impact mining activity in European coal regions. Works within the first project task were focused on identification and documentation of extreme events in mining industry in project partners countries (Greece, Czechia, Poland, Germany, Spain and United Kingdom).

The most likely severe weather events resulting from climate change have been considered. For each, the likely impacts to working and abandoned mines are listed, and some reference has been made to the impact on European regions. The direct impacts, which are primarily physical in nature and could be on of off-site have been identified. Dozens of events in the mining sector have been identified that can be directly related to the previously occurring extreme weather phenomena. What's important, the connection between hazard and their impact may occur over the short-, medium-or long-term.

Significant climate-related events that have already impacted on mining activities have been identified and recorded, in order to identify the main impacts of the events, responses to these events and key lessons learnt from these experiences. Database of these events has been created and will be maintained throughout the Project TEXMIN. Currently, the database contains information on 25 events in the UK, 25 in Poland, 3 in Greece, 2 in Spain, 7 in Germany and 5 in the Czech Republic.



Database of Past Extreme Weather Events Affecting the Mining Industry

Date of Incident	Country	Location	Mine Name	Working or Abandoned	Mine Type	Incident Type	Description	Response	Lessons Learned	Extreme Weather Cause Suggested by Experts or in Media?	Weather Statistics	Reference Document(s)
21 October 1966	UK	Aberfan, South Wales	Merthyr Vale Colliery	Working	Coal	Spoil heap slide	School and houses destroyed, 144 fatalities	Massive rescue, clean-up and rebuilding operations	New laws were introduced placing regulations on spoil heaps	Heavy rainfall in October, especialy previous week, considered main cause	Rainfall 19.39mm, 2.30, 7.59, 11.39, 13.39, 12.69 on 14th - 19th	https://en.wikipedia.org/wiki/A
03 February 2002	UK	Redruth, Cornwall	Pednandrea Mine	Abandoned	Copper, tin	Shaft collapse	200 foot shaft opened in garden of house	New cap built over shaft		Reference to "torrential rain" in news story	Rainfall 10.55mm, 13.53mm, 6.35mm in 3 days before event	http://news.bbc.co.uk/1/hi/engl
17 October 2002	UK	Northumberland Park, North Tyneside	Unknown	Abandoned	Coal	Shaft collapse	Hole appeared in metro rail track near station				Wet month (25mm 9/10th) but drier in past week	http://news.bbc.co.uk/1/hi/engl
01 April 2010	UK	Wednesbury	Unknown	Abandoned	Limestone	Shaft collapse	Hole in football pitch				Rainfall 7.03, 6.20mm 3 and 2 days earlier, 3.82mm on day	https://www.expressandstar.com shaft-appears/
18 November 2010	UK	Tirphil, New Tredegar, South Wales	Tirphil Colliery?	Abandoned	Coal	Shaft collapse	Hole opened in road next to railway line	Filling of shaft, remedial work on road		Reference to heavy rain at 19:00 on 17-Nov in news story, MISSTER paper refers to inflow from culvert	Rainfall 13.76, 8.96mm on 2 days befc	https://www.walesonline.co.uk/ 1886756
14 August 2011	UK	Crusader Ave., Knightswood, Glasgow	Unknown	Abandoned	Coal and Iron	Shaft collapse	Hole in housing area, four properties evacuated and subsequently demolished	Filling of shafts			Rainfall 14.13, 23.58, 25.66, 7.2, 8.86mm on 6th, 9-12th	http://www.themime.org.uk/wp for-web.pdf
10 June 2012	UK	Aberystwyth, Wales	Several mines	Abandoned	Lead, zinc	Minewater discharge	Contamination of land and killing of livestock	Response mostly related to general flooding, not	Welsh government committed to flood risk management	High rainfall, flooding, caused discharge	Local rainfall: 17.4, 30.6, 52.8, 91.4, 117.2, 120.6mm previous	https://www.bbc.co.uk/news/uk
12 February 2013	UK	Hatfield, Yorkshire	Hatfield Colliery	Working	Coal	Spoil heap slide	Railway lines severely damaged	Remedial work to reinstate railway service lasting almost 6 months		BGS report suggests probably due to heavy rain	Long term continuous rain during winter (especiall late December), 21.24mm on day after event, causing	https://www.bgs.ac.uk/research s/landslides/HatfieldFeb2013.ht
17 February 2014	UK	River Colne, Jackson Bridge	Unknown	Abandoned	Coal?	Minwater discharge	River pollution (orange)	No remedial work undertaken	Conclusion was that dischagres here (there have been several) are not acidic and do not pose a	Heavy rain	Rainfall 11.48, 17.00mm on 12th, 14th	https://www.examinerlive.co.uk orange--6719210
20 January 2014	UK	Camborne, Cornwall	Unknown	Abandoned	Metals	Shaft collapse	House partially fell into hole				Rainfall 8 days > 10mm (1 day 19.96mm) in month to date	https://www.aol.co.uk/2014/01/
12 February 2014	UK	Gilligham, Kent	Unknown	Abandoned	Chalk	Mine collapse	Hole in school sports field	Hole filled with foamed concrete		News report refers to "the week's torrential weather"	12.04, 21.29, 10.07mm on 4, 6, 12, period from December 2013 to January 2014 was one of, if not the most, exceptional periods of winter rainfall in the last 248 years for	https://www.kentonline.co.uk/r 12799/
20 November 2015	UK	Gosforth, Newcastle	Coxlodge Colliery	Abandoned	Coal	Shaft collaose	Hole in carpark adjacent to houses	7-month capping and repair project			Rainfall 23.65mm on 14th, 9.93mm on 17th, 9.99mm on 18th	https://www.dailymail.co.uk/ne SINKHOLE-opens-estate-built-ol
12 May 2016	UK	Greenwich, London	Unknown	Abandoned	Chalk	Shaft collapse	Car fallen into hole in road			Reference in news report to overnight storms and heavy rain	Rainfall 4.17, 14.08, 4.19mm on 9th - 11th	https://www.independent.co.uk street-car-hole-london-a7025301
09 January 2017	UK	Hardgate, West Dunbartonshire	Unknown	Abandoned	Limestone, iron, coal	Shaft collapse	Hole in road	6-month caping, reinstasting services and			Rainfall 10.02mm, 7.07, 8.97, 9.36mm on 5th, 6th, 8th, 9th	https://www.clydebankpost.co.u metres-deep-and-caused-by-his

Figure 1 – Extract of Continually Updated Database of extreme events in mining related to climate change

This file presents selected examples of mining catastrophic events associated with extreme weather events from those identified and compiled within TEXMIN project. Many of these events are related to current mining operations which have not only implications for on-going works, but also may impact the company when the mine is closed or closing, although also events impacting post mining activities and areas have been taken into consideration.

As main important following climatic parameters have been taken into consideration: temperature, precipitation and atmospheric pressure.

PRECIPITATION

Heavy rainfall negatively affects mine geomorphology and drainage and therefore can be a contributor to several types of mine-related incidents including:

- collapse of abandoned shafts or shallow mine workings,
- stability problems waste disposal areas, e.g. causing landslides involving spoil heaps,
- slope stability issues in opencast operations,
- flooding of working mines (especially opencast mines) and access roads,
- tailings dam failures and consequential flooding,
- damage to or losses of machinery and equipment;
- releases of contaminated mine water into surface watercourses,
- increased risk of personnel injury.

On the other hand, also potential water scarcity could have significant impacts on mining activity. During the coal mine operation large quantities of water are used for the extraction and minerals processing and also for the maintenance of restoration of infrastructure and further natural assurance measures. Therefore, prolonged droughts may adversely affect mine water withdrawals and exacerbate the water-use pressure on water-intensive processes, causing an increased need for irrigation of rehabilitation works as well as more frequent wildfires, which could threaten mine equipment or assets.

The analyses performed confirmed that heavy rainfall combined with extreme drought can be significant factors affecting the stability of pit slopes in active opencast mines (e.g. Turów Lignite Mine, Poland).

Figure 2 – Turów lignite mine – slope stability loss after heavy rainfalls, 2016

Source of photo: *https://zgorzelec.naszemiasto.pl/kwb-turow-ziemia-caly-czas-sie-przesuwa-wstrzymano-dostawe/ar/c3-3870126*

Large parts of Wales (UK) were affected by flooding after Storm Christoph brought heavy rain. On 21 January 2021, following Storm Christoph and prolonged wet weather across Wales a large volume of water flooded into Skewen from mine workings in Goshen Park.

Authorities have been investigating the case and the early indications are that it is linked to a disused mine in the area (Skewen mine) the potential of a "burst mineshaft" being the cause.

Figure 3 – Skewen, South Wales UK. Mine water inrush after Storm Cristoph,2021

Source of photo: *https://www.walesonline.co.uk/news/wales-news/skewen-flooding-rain-mineshaft-wales-19677848*

High levels of iron in water from abandoned underground mine was the indicator of direct relation of high precipitation and mine water inrush from old coal mine. As a result of this event, it is planned to build a new

mine water management system to capture the water coming down from the mines above Skewen to reduce the risk of such an event happening again.

Flooding in mines - both opencast and underground mining - was also associated with the destruction and the necessity of evacuation of workers many times, such as in 2010 at Brzeszcze (PL) , where the embankment of the mine tailings pond was breached, and at the Siemianowice mine (PL), where water inrush into the pumping station and mine workings was identified. Although these events are not explicitly linked to climate change in mining documentation, it is clear because in 2010 extreme rainfall and flooding affected the whole of southern Poland.

Also in Greece, the principal cause for mining-affecting incidents was extreme precipitation – specifically extreme rainfall or snowfall. The winter of 2002-2003 was characterized as the most severe winter of the last 50 years in Greece. The snowfall was too high and it led to the closure of the Western Macedonia lignite mine for 20 days. During this time, lignite extraction was impossible. This resulted in increased energy costs for Greece, and the country faced the threat of the loss of energy supply.

Figure 4 – Western Macedonia Lignite Centre: Heavy Snow Events Winter 2002-2003

Source of photo: www.prlogos.gr

Regarding the relationship between rainfall and the effects on mining activity, no specific cases have been found in Spain, as there is a lack of formal information regarding the mines affected by heavy rainfall. However, a series of conclusions and hypotheses of the possible effects that mining activity has suffered with respect to extreme weather events can be established. The most prominent case is the Aznalcóllar disaster in 1998, where there was a breakage of the dam due to a technical failure, and the flow released affected the raft of the Aznalcóllar mine resulting in large leaks of contaminating sludge and heavy metals, producing a catastrophic environmental impact.

Figure 5 – Aznalcóllar Disaster of 1998

Source of photo: *https://principia.es/en/20-years-since-aznalcollar/*

Slope landslides in 2008, 2009 and 2013 in quartz sand open pit mines of the Halterner Sande (DE) have caused failures in mining operations. An area of 8,000 m² was affected by the landslides. According to investigations, changes in pore water pressure, changes in water flow due to changes in ground water levels or precipitation events, as well as dynamic and static loads on the slopes may have contributed to the landslides.

A shaft collapse at the Szczygłowice coal mine in the western part of GZW, Poland took place on 4th of September 2008. It was a severe mining event which was investigated and identified as a building catastrophe. Construction of the shaft tower and buildings were in very poor condition, and the stability of the surface was never investigated in relation to climate and weather events.

Figure 6 – Shaft Collapse – Szczygłowice Coal Mine

Source of photo: *Dziennik Zachodni, 2008*

In July 2009, after heavy rainfall, an 11m deep hole with a diameter of 1. 5ms was suddenly created on motorway 45 between Olpe and Freudenberg (DE), caused by the collapse of a former mining shaft from 1909. An estimated 70 to 100 cubic meters of concrete were needed to fill the hole.

Figure 7 – Deep hole over the old shaft

Source of photo: https://www1.wdr.de/archiv/bergbau-spaetfolgen/bergbau_spaetfolgen274.html

TEMPERATURE

High temperatures are the most well-known effect of climate change, the condition generally being referred to as global warming. This affects most areas of the world while, in Europe, the southern areas are predicted to be the most severely impacted.

Unusually high temperatures may negatively affect the mining industry by reducing productivity, hindering rational decision making, increasing personnel absenteeism, and heightening the risk of heat-related illnesses. For example, already in summer 1991, due to extreme heat, at the Western Macedonia Lignite Centre, works stopped for many hours in order to avoid heatstroke.

Additionally, an increased temperature along with decreased rainfall may impact water-dependent mines, as well as water-dependent mine tailings facilities.

ATMOSPHERIC PRESSURE

The potential for low atmospheric pressure to increase the likelihood of methane release from coal measures into working mines is well known, and similar arguments apply to migration of gasses from abandoned mines to the surface. A summary of the risk, therefore, includes:

- outgassing of methane from coal in working mines, leading to increased explosion risk,
- release of carbon dioxide to the surface, with the risk of oxygen starvation,
- release of carbon monoxide to the surface, with the risk of poisoning,

- and release of methane to the surface, with the risk of fire or explosion.

For example, on July 27, 2016, there was a sudden outflow of methane from the goaf to the F-1103 roadway, the F-32 cross-cut and the F-32 drift at Murcki – Staszic Coal mine (PL). Atmospheric pressure fluctuations were indicated as the cause of the outflow. On the day directly preceding the event, an increase in atmospheric pressure of 1.9 hPa was registered. Whereas on the day of the event, within 5 hours, the pressure dropped by 4.2 hPa. The result of these fluctuations was the outflow of methane to the excavations, followed by the explosion of the methane-air mixture. As a result of the explosion, 1 miner died and the shaft bank buildings were damaged.

SUMMARY

Mining operations are increasingly being hampered by extreme climatic events such as extreme rainfall, intense storms, heat waves and droughts. Therefore, in mining- similarly as in many other industrial activities, it has to be now better accepted that some level of adaptation is required in order to deal with the effects of climate change. Especially that as the climate continues to warm up, extreme weather events are predicted to become more frequent and intense.